Sampling Bark Beetle Emergence: a Review of Methodologies, a Proposal for Standardization, and a New Trap Design

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Sampling methodologies have been developed for various species of bark beetles including the mountain pine beetle (Carlson and Cole 1965), western pine beetle (Berryman et al. 1970, DeMars 1970), and the southern pine beetle (Coulson et al. 1975, Stephen and Taha 1976). Within-tree sampling involves removal of bark sections and utilization of dissection or radiography to obtain quantitative data for each life stage.

Emergence, on the other hand, is a more difficult phenomenon to sample and a considerable variety of techniques has been used in recent years. Basically, emergence estimates have been derived from 2 types of procedures; those which do not interrupt or modify on-going physical or biological processes within the tree (nondisruptive) and those which do (disruptive). Techniques which have been utilized include counts of exit holes and teneral adults beneath the bark, rearing cages in field or environmental chambers in the laboratory and traps placed on standing trees.

The objectives of this paper are: (1) to review the various techniques which have been used to estimate emergence and to discuss their inherent advantages and disadvantages; (2) to propose that a standard procedure be adopted in order to minimize bias and to facilitate comparison of data among workers; and (3) to introduce a new emergence trap which should prove useful for studies of bark beetles as well as other bark inhabiting species.

Procedures Utilized in Sampling Beetle Emergence

Nondisruptive sampling techniques correlate emergence with counts of exit holes assuming that: (1) each beetle excavates its own hole upon emerging from the tree, and (2) that these points of exit can be distinguished from all other types of holes, i.e., entrance and ventilation as well as those made by other species (Giolovjanko 1926, Patterson 1927, Inouye and Yamaguchi 1955, Reid 1957, Miller and Keen 1960, McMullen and Atkins 1961, Berryman 1968, Sartwell 1971).

The advantage of this technique lies in the fact that the tree remains unaltered until emergence is complete. While theoretically desirable, in actuality this procedure presents some major problems. Comparisons of emergence within enclosures to counts of exit holes have shown that a one-to-one ratio does not always exist. Multiple use of a single hole and utilization of natural cracks and fissures in the bark commonly occur (Hain and McClelland unpublished, Struble and Hall 1955, Miller and Keen 1960, McMullen and Atkins 1961, Sartwell 1971). In a number of studies "correction factors" have been developed to account for these phenomena (McMullen and Atkins 1961, Reid 1963, Sartwell 1971). Determination of an accurate correction factor requires considerable effort with no guarantee of applicability to other times and locations.

Spatial and temporal variations in brood development present a problem in utilizing the exit hole procedure. It is difficult to determine the specific time when emergence is complete. Removal of bark before all brood has exited will result in further underestimation; to delay sampling incurs the risk of bark destruction by insects, birds, and natural sloughing as the tree deteriorates. Upon completion of emergence the integrity of the bark has often been dramatically impaired. Under these conditions, acquisition of data is extremely difficult and even impossible in many situations.

Because of the above limitations, few researchers have adopted the exit hole technique. The methodologies commonly utilized include field cages, environmental chambers, and traps attached to trees. All involve some interference with biological processes operating during the final development period before emergence. The degree of influence varies with the technique and its application.

The disruptive techniques include those which measure actual emergence and those utilizing potential emergence. Potential emergence estimates from with-tree sampling of teneral adults have been reported for the Black Hills beetle (Knight 1959) and the Engelmann Spruce beetle (Trägårdh and Butovitsch 1935, Knight 1969, Thatcher 1967, Dyer and Taylor 1971). The advantage of this technique is that it requires a minimal amount of time. However, equating potential with actual emergence will inevitably result in overestimates because of failure to account for mortality occurring during the interim period before the brood adults exit the tree. Reid (1963) determined that 10% of mountain pine beetle teneral adults never emerged.

An additional drawback with this procedure results because of the variation in brood development at different locations along the bole. This necessitates repeated sampling of the tree. Sampling at a single point in time would result in counts of several life stages producing possibly even larger overestimates.

Actual emergence estimates have been obtained by placing bolts or bark sections in cages in the field (McMullen and Atkins 1961, McCambridge 1964, Thatcher and Pickard 1964, 1967) or under controlled environmental conditions in the laboratory (Cole 1962, Sartwell 1971, Coulson et al. 1975). Once setup, these procedures provide an efficient way to measure emergence; however, the effort required to collect the substrate is considerable. Brood reared in field cages or the laboratory can be exposed to substantial differences in microclimate than that which would naturally occur within the tree. Correlation of emergence patterns with in situ phenomena are not pos-

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sible. Removal of a portion of bark isolates or partially isolates the brood therein from those biotic factors which are operating within the tree.

The net effect of rearing in field cages or in the laboratory can be variable. Failure to maintain an adequate microclimate within the substrate can result in excessive mortality while elimination or interference with predation and parasitism will ensure higher survival.

Because of the inherent problems associated with the above mentioned procedures, the authors believe that the most practical and unbiased estimates of emergence are obtained by on-tree trapping utilizing traps that are properly constructed and installed. While the outer bark area beneath the trap becomes a closed system, the inner bark environment remains unaltered. Except for interference with parasitism of late brood stages, it is believed that the net effect on the sampled population is minimal.

From a practical standpoint, the error in regard to late brood parasitism while an unknown quantity is an acceptable bias in comparison with drawbacks of other procedures. Interference with parasitism can be minimized by placement of traps as late as possible in the development period but yet early enough to account for all emergence.

During certain times of the year, woodpecker foraging can result in significant mortality to within tree populations. Under these circumstances estimates of survival and emergence using traps will require an adjustment. However, accounting for avian predation is a requirement for any of the aforementioned sampling methodologies.

A variety of traps has been used in studies of bark beetle ecology (Miller and Keen 1960, Dyer 1963, Reid 1963, McCambridge 1964, McCambridge and Knight 1972, Schmid 1972, Amman and Rassmussen 1974, Coulson et al. 1975). Problems associated with these traps include: difficulty and awkwardness of use, modification of temperature and humidity within the trap, isolation of the brood within the bark area encompassed by the trap, and variations in size of the sample area.

Design of a New Emergence Trap

Introduced is a new emergence trap which overcomes many of the disadvantages of traps used in previous studies. Included is a discussion of the construction and modifications of this trap.

The emergence trap (Fig. 1A) consists of a 18×18-cm base plate which is made of 28-gauge galvanized metal. A 11.3 cm diam hole in the center of the plate equals a sampling area of 100 cm^2. A small hole is drilled on each side to accommodate nails for attachment to the tree. For safety, the sharp corners are rounded.

A 2.5×38-cm strip of 28-gauge, galvanized metal is cut, overlapped, and spot-welded to form a net attachment ring. The ring is soldered to the base plate at points adjacent to the nail holes. Four small holes are drilled into the ring for attaching the net. A 3×36-cm strip of foam pad is glued to the back of the base plate around the 100-cm^2 hole with Weldwood® contact cement.

The trap net is made of 30-mesh nylon screen. The net pattern is illustrated in Fig. 1B. A 5-cm "pleat" cut on either side of the fold line overlapped and sewed together provides a secure fit for the 66-mm polypropylene funnel. The edges of the net are reinforced with a zig-zag stitch. The net is folded along the "fold line" and zig-zag stitched along the dotted lines (Fig. 1C). The seams are double stitched for reinforcement.

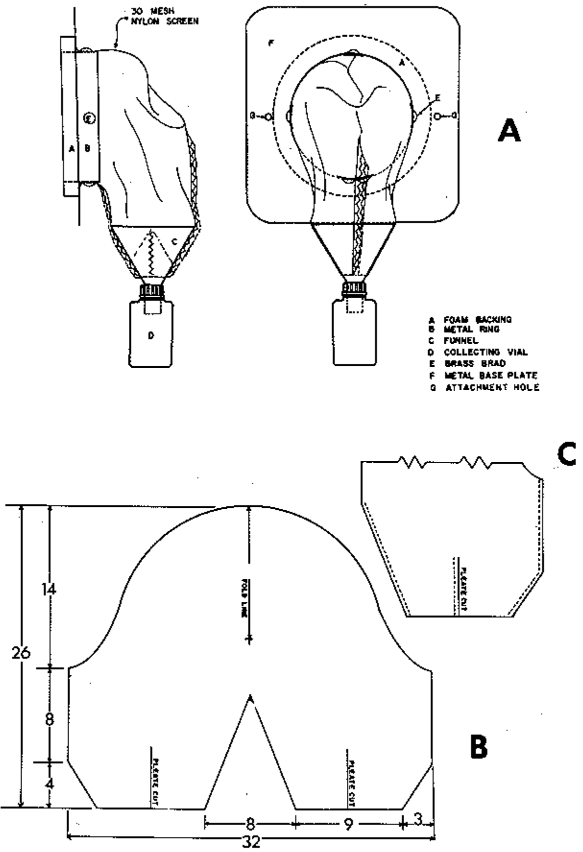

FIG. 1.—A. Schematic of NCS emergence trap. B. Net pattern for emergence trap. C. Stitch lines for net.

The funnel is inserted into the net with the shaft extending beyond the pleated edge. Gluing the funnel into the net is facilitated by twisting and securing the net above the top opening of the funnel. Weldwood® plus 10™ contact cement is liberally applied to the funnel but not the exposed shaft. Cement should be applied in sufficient quantity to prevent gaps forming between the net and the funnel.

The net assembly is attached to the metal ring with brass paper fasteners. The net opening must be tightly stretched around the ring before the paper fasteners are inserted. Excess material should be folded over the attachment hole before securing with the last fastener.

The final step involves placing the collecting bottle cap onto the funnel shaft. Drilling a hole in the center of the cap slightly smaller than the outside diam of the funnel shaft will ensure a tight fit for the cap, which remains permanently on the trap. The bottle is pushed onto the funnel shaft and secured to the cap.

The most satisfactory killing agent for the collecting bottle is a small piece of vapona strip (Shell No-Pest® Strip). Water accumulation can be eliminated by drilling small holes in the bottom for drainage. Insects can be prevented from escaping by placing several layers of netting above the drainage holes. The vapona strip kills trapped insects quickly and remains effective up to 60 days.

Several liquid preservatives (Kersone, water, ethylene glycol) have been used in the collecting bottles. However, problems arise when precipitation dilutes or washes out these materials. This can result in deterioration of soft bodied insects, especially during periods of warm weather. Plastic, acetate or other waterproof material placed over the nets will help prevent water accumulation.

Modifications of Basic Trap Design

Modification of the basic trap design (NCS trap) have been developed at Texas A&M University (TAM trap) and Mississippi State University (MSU trap). These modifications are illustrated in Fig. 2.

The TAM trap (Fig. 2A) consists of a 20×20-cm galvanized metal plate with a 11.3-cm center hole and 4 (attachment) holes at the corners. The net (pattern shown in Fig. 2B) is assembled by gluing the seams with Devcon® epoxy adhesive and filler and attaching the Kimble 2-oz wide-mouth bottle cap to the net with Devcon® 5 epoxy Dev-Tube. The net is stapled to the back side of an 8-inch square of cardboard (300 weight illustration board) which has been waterproofed with REZ® plastic coat. The cardboard-net assembly is then glued to the metal base plate with contact cement. Weather-stripping is glued to the back of the metal base plate around the center hole.

The MSU trap (Fig. 2C) consists of a 4-cm galvanized ring which has been riveted together. An L-shaped bracket on each side serves to attach the trap to the tree. Weather-stripping is glued to the outside of the ring along the inner edge. The net is similar to that of the NCS trap.

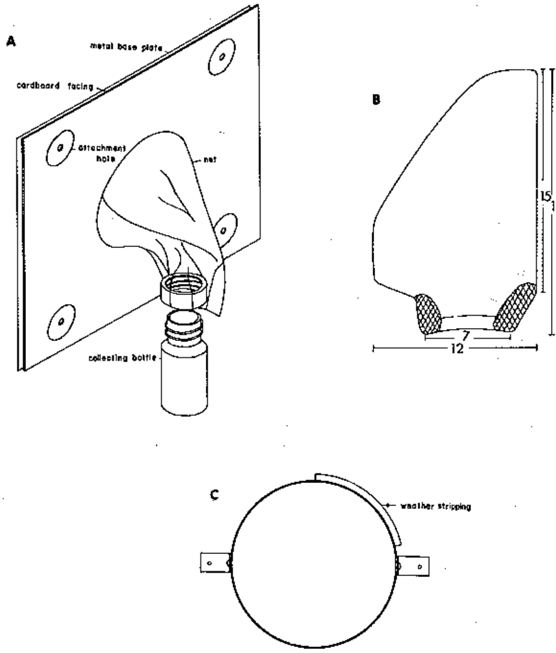

FIG. 2.—A. Schematic of TAM emergence trap. B. Net pattern for TAM trap. C. Schematic of MSU trap (without net).

Conclusions

Deriving accurate estimates of within tree emergence presents researchers with unique sampling difficulties. As noted, there is no entirely satisfactory technique for accomplishing this task.

Exit hole counts, while nondisruptive, prove unworkable in many situations. Acquisition of data is often subjective and results can be quite variable. Other procedures interrupt certain physical and biological processes which are operating within the tree. Utilization of potential emergence, field cages, or environmental chambers result in greater interference to natural processes than do traps.

The authors believe that on-tree trapping provides the most practical solution to the problem. With proper design and placement as well as careful timing of sampling, traps will provide emergence data that are relatively unbiased and comparable between studies.

The emergence trap introduced herein is proposed as a standard technique for estimating bark beetle emergence. The traps are rugged, easy to use, and adaptable to a variety of situations. They can be positioned on the tree and removed quickly. They attach easily to trees 13 cm diam or larger. With the addition of 1 or more layers of foam padding the NCS and TAM traps can be used on even smaller diam material.

The sample area of ca. 100 cm² is a convenient size and one which has been adapted for quantitative studies of several species of bark beetles. The trap can be attached without cutting into the tree, thereby isolating the inner bark environment. The screen enclosure prevents the buildup of temperature and moisture inside the trap which could possibly influence survival and emergence.

Of primary importance in understanding the population dynamics of any species of bark beetle is the ability to compare data in regard to differences in time, geographic location, population status, climatic conditions, host species, and other environmental variations. A standardized procedure of sampling emergence is a major step toward solution of this problem.

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